3P4-11

The Onset Temperature Measurement of the Straight-Tube-Type Thermoacoustic System with Diameter-Expanded Prime Mover : Influence of the Expanded Part Length

内径拡大プライムムーバーをもつ直管型熱音響システムの拡大部長さと発振温度について

Kohei Egawa[1‡], Shin-ichi Sakamoto[1], Yuichiro Orino[1],and Yuya Yamaga[1]
([1] Univ. of Shiga Pref.)
江川航平 [1‡]，坂本眞一 [1]，折野裕一郎 [1]，山鹿祐弥 [1] ([1] 滋賀県立大)

1. Introduction

Thermoacoustic[1)] systems are expected to be an effective technique for the utilization of thermal exhaust energy. However, these systems need high temperatures of 300-500°C to drive. In order to expand the fields of application and reuse the low-temperature exhaust heat below 200°C, many studies have been conducted on decreasing the onset temperature.[2-9)] The proposed method for decreasing the onset temperature includes a thermoacoustic system with a multi-stage prime mover having an expanded diameter[2,6-9)], as well as the installing multiple regenerators in the system.[3,4)]

By using these methods, we developed a loop-tube-type thermoacoustic system with diameter-expanded two-stage prime movers. We succeeded in driving the system at approximately 67°C.[6)] In the above study, a heat pump had been removed. For the next step, we developed a prototype thermoacoustic cooling system which could be driven at approximately 80°C and the cooling point temperature was decreased by 5.8 K from 20°C.[8)] In these studies, the length of the expanded part is not optimized. For practical use, the influence of the expanded part at the onset temperature must be investigated.

In the present study, we focused on expanded part length. As a beginning, we confirmed the influence of the expanded part length on the onset temperature in the straight-tube-type system likewise loop-tube-type system and experimentally investigated the onset temperature by changing expanded part length.

2. Experimental system and methods

Figure 1 shows a schematic of the experimental system. The straight-tube-type thermoacoustic system with a diameter-expanded prime mover is comprised of stainless steel tubes filled with atmospheric pressure air. The total length

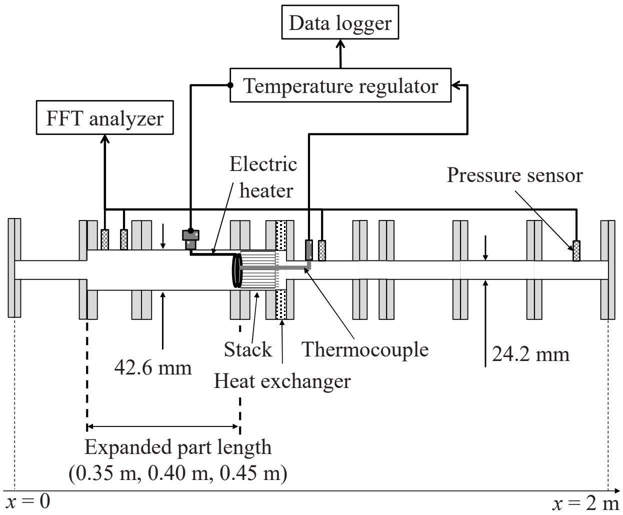

Fig. 1 Experimental system.

of the system was 2 m. Both tube ends were sealed. The inner diameters of tubes were 42.6 mm and 24.2 mm. The expanded part lengths were 0.35 m, 0.40 m and 0.45 m, respectively. The stack consisted of ceramic honeycombs, which had a length of 50 mm and a channel density of 600 channels/in^2. The installation position of the stack was x = 0.6 m. In experiments at each expanded part length, a channel density of the stack and installation position of the stack was the same. Water at 20°C was circulated through the heat exchanger to maintain this temperature on the constant temperature side of the stack. An electric heater was used as the heat source.

The sound pressure was measured by four pressure sensors (PCB Piezotronics, 112A21). We confirmed spontaneous thermoacoustic oscillation by using these pressure sensors and a FFT analyzer. The temperature of the heating point was measured by K-type thermocouple. An electric heater was connected to a temperature regulator and the input power was controlled.

The experimental procedure was as follows.

E-mail: ot23kegawa@ec.use.ac.jp

First, the stack was heated using an electric heater to generate spontaneous thermoacoustic oscillation. Second, we confirmed spontaneous thermoacoustic oscillation by using four pressure sensors and a FFT analyzer. Third, by changing the input power to an electric heater using a temperature regulator, the temperature of the heated end of the stack was constantly maintained. Then, the temperature of the heated end of the stack was gradually decreased using a temperature regulator until the spontaneous thermoacoustic oscillation disappeared. After confirmation of disappearance, we waited for 10 minutes and confirmed that it could not resume oscillating. The temperature at which spontaneous thermoacoustic oscillation just before disappeared was defined as the onset temperature.

3. Experimental results and Discussion

Figure 2 shows the onset temperature obtained by the experiment at each expanded part length. The onset temperatures were 203°C, 214°C, and 227°C for expanded part lengths of 0.35 m, 0.40 m, and 0.45 m, respectively. The lowest onset temperature was 203°C for expanded part length of 0.35 m. As the expanded part length becomes longer, the onset temperature increases by about 10°C.

Figure 3 shows the frequency of the spontaneous thermoacoustic oscillation obtained by the experiment at each expanded part length. The frequencies were 83.3 Hz, 82.4 Hz, and 81.3 Hz for expanded part lengths of 0.35 m, 0.40 m, and 0.45 m, respectively. As the expanded part length becomes longer, the frequency decreases by about 1 Hz. A change of frequency arising from the difference in the expanded part length could be considered one of causes of the difference in onset temperature.

These results show that the onset temperature changed about by 10°C, while the frequency of spontaneous thermoacoustic oscillation hardly changed. With the exception of the change of frequency, there are the factors that contribute to the onset temperature.

4. Conclusion

We experimentally investigated the influence of expanded part length on the onset temperature. The results show that the onset temperature changed by about 10°C as the expanded part length changed, whereas the frequency of spontaneous thermoacoustic oscillation hardly changed. We confirmed that, with the exception of the change of frequency, there are the factors that contributed to the onset temperature.

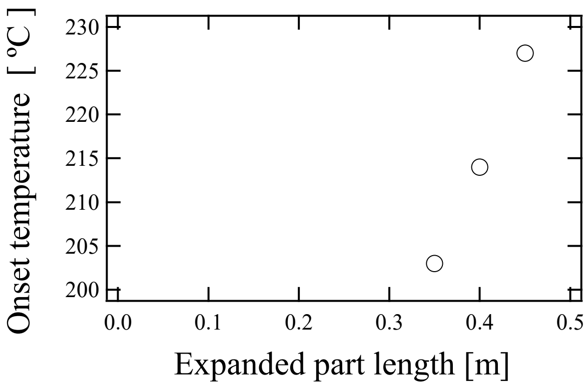

Fig. 2 Onset temperature obtained by the experiment at each expanded part length.

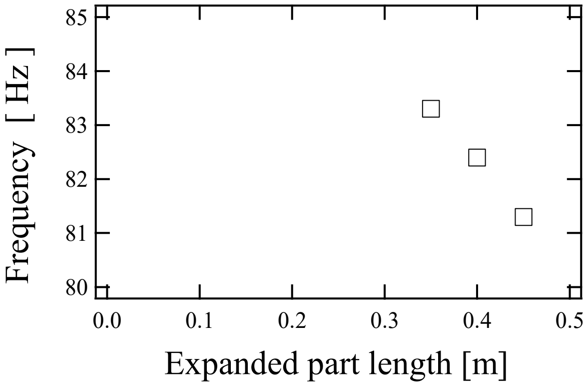

Fig. 3 Frequency of spontaneous thermoacoustic oscillation.

Acknowledgments

This work was supported by the JSPS Grant-in-Aid for Young Scientists (A) (Grant No. 22686090), JSPS Grant-in-Aid for Challenging Exploratory Research (Grant No. 23651072), Grant-in-Aid for Scientific Research (C) (Grant No. 40449509), Program for Fostering Regional Innovation, and JST Super Cluster program.

References

1. A. Tominaga: Cryogenics **35** (1995) 427.
2. K. de Block: Proc. ASME FEDSM-ICNMM vol. **2** (2010) 73.
3. T. Biwa *et al.*: Appl. Phys. Lett. **97** (2010) 034102.
4. S. Hasegawa *et al.*: Appl. Therm. Eng. **58** (2013) 394.
5. Y. Orino *et al.*: Jpn. J. Appl. Phys. **53** (2014) 07KE13.
6. T. Ishino *et al.*: Jpn. J. Appl. Phys. **54** (2015) 07HE11.
7. X. Zhang and J. Chang: Energy Convers. Manage. **105** (2015) 810.
8. S. Ueno *et al.*: Jpn. J. Appl. Phys. **55** (2016) 07KE13.
9. S. Ueno *et al.*: Jpn. J. Appl. Phys. **56** (2017) 07JE07.